CHARACTERIZING THE RANGE OF CHILDREN'S POLLUTANT EXPOSURE DURING SCHOOL BUS COMMUTES

ABSTRACT and EXCUTIVE SUMMARY

Prepared for the California Air Resources Board
Contract No. 00-322

Principal Investigator

Dennis R. Fitz

College of Engineering
Center for Environmental Research and Technology
University of California
Riverside, CA 92521

Co-Principal Investigators

Arthur M. Winer, Ph.D. and Steven Colome, Sc.D.

Department of Environmental Health Sciences
School of Public Health
University of California
Los Angeles, CA 90095

Participating Researchers

Eduardo Behrentz, Lisa D. Sabin, Seong Jeong Lee, Kenneth Wong, Kathleen Kozawa

Department of Environmental Health Sciences
School of Public Health
University of California
Los Angeles, CA 90095

David Pankratz, Kurt Bumiller, David Gemmill, Matt Smith
College of Engineering
Center for Environmental Research and Technology
University of California
Riverside, CA 92521

October 10, 2003

ABSTRACT

To determine the range of children's exposures during their bus commutes, especially those conditions leading to high exposures, real-time and integrated measurements of pollutant concentrations were conducted inside five conventional diesel school buses, as well as a diesel bus outfitted with a particulate trap and a bus powered by natural gas. Measurements were made during 20 bus commutes on a Los Angeles Unified School District bus route from South Central Los Angeles to the west side of LA, with additional runs on a second urban route, a rural/suburban route, and to test the effect of window position.

Children's school bus commutes in Los Angeles appear to expose them to significantly higher concentrations of vehicle-related pollutants than ambient air concentrations and frequently higher concentrations than those measured on roadways. Concentrations of diesel vehicle-related pollutants such as black carbon and particle-bound PAHs were significantly higher on board conventional diesel buses when windows were closed. This was due to the intrusion of the bus's own exhaust, as demonstrated through the use of a tracer gas added to each bus's exhaust. When windows were open, increased ventilation rates markedly reduced this effect, although high peak concentrations were then observed when following other diesel vehicles. On-board concentrations of vehicle-related pollutants were also significantly higher on the urban routes compared to the rural/suburban route, indicating the importance of surrounding traffic density.

Other related exposure scenarios such as bus loading and unloading, and time spent waiting at bus stops, were shown to make relatively insignificant contributions to children's exposure, due to the generally lower concentrations and the short times spent at those activities compared to bus commutes. Results from this study show that minimizing commute times, using the cleanest buses for the longest routes, and reducing bus caravanning and idling time will reduce children's exposure to bus-related pollutants.

1.0 EXECUTIVE SUMMARY

Background. Because children's lungs are still developing and children are more susceptible to adverse health effects from air pollution, potentially high pollutant exposures during school bus commutes are of concern. Studies of pollutant concentrations inside vehicles show high exposures are typical, but few studies have attempted to characterize concentrations on-board and near school buses. This study's main purpose was to determine the range of children's exposures during their bus commutes, with an emphasis on determining the specific factors and conditions leading to high exposures and comparing the effects of different bus and traffic characteristics and bus operating conditions.

Methods Real-time and integrated measurements of pollutant concentrations were conducted in the spring of 2002 while driving school bus routes in Los Angeles (LA) with five conventional diesel school buses, manufactured from 1975 to 1998, a 1998 diesel bus outfitted with a particulate trap, and a 2002 bus powered by natural gas. All diesel buses used low sulfur "green" diesel fuel. Runs included ten morning and ten afternoon bus commutes over an LA Unified School District (LAUSD) bus route from South Central LA to the west side of LA, with four additional runs on a second LAUSD urban route, seven additional runs on a rural/suburban route, and to three additional runs to test the effect of window position.

Results: Bus stop and bus loading/unloading activities were shown to make small contributions to overall commute-related exposures due to the low concentrations found there and the short lengths of time involved in those activities. Exposure factors calculated were as much as two orders of magnitude higher for bus commutes on urban routes than for the bus stop or loading/unloading microenvironments (Table 1.1).

Table 1.1 Average exposure factors (air concentration * time) in three microenvironments.

	Loading/Unloading[1]	Bus Stops[2]	Urban Commutes[2]
Black Carbon ($\mu g/m^3 * min$)	5	20	600
Particle-Bound PAH ($ng/m^3 * min$)	45	230	10000
NO_2 (ppb * min)	105	270	5500
Particle Counts (#/cm3 * min)	25	310	10000
PM2.5 ($\mu g/m^3 * min$)	N/A	130	3500

[1]Based on measurements taken during pilot study. [2]Based on five min. spent at bus stop and a 76 min. commute.

Overall, children's school bus commutes in Los Angeles appear to expose them to significantly higher concentrations of vehicle-related pollutants than ambient air concentrations and frequently higher concentrations than those measured on roadways. Self-pollution from the bus's own exhaust was found to play a significant role in on-board bus concentrations, especially when windows were closed, as was demonstrated by on-board measurements of an inert tracer gas, SF6, added to each bus's exhaust. Older buses showed higher rates of exhaust intrusion, but intrusion was detected in all buses. With closed windows, mean concentrations of diesel vehicle-related pollutants such as black carbon and particle-bound PAHs on board conventional diesel buses were more than double the mean concentrations with windows open. Under closed window conditions, diesel vehicle-related pollutants were also significantly higher on-board the conventional diesel buses as compared to the single CNG-powered bus, while the trap-equipped

bus had concentrations between the two (although diesel-related pollutant concentrations on board this specific trap-outfitted bus appeared to be higher than expected based on emissions data reported for other trap-equipped diesel vehicles). In contrast, natural gas-related pollutants such as formaldehyde were higher aboard the CNG bus. With closed windows, concentrations were also somewhat higher in the rear of the bus, but front/rear differences were generally smaller than the bus-to-bus concentration differences. When windows were open, the resulting high ventilation rates appeared to strongly reduce the amount of self-pollution, while the influence of following individual vehicles became more pronounced, and high transient concentrations of diesel vehicle-related pollutants were associated with proximity to other diesel vehicles.

On-board concentrations were also strongly influenced by other traffic sources. Table 1.2 presents the mean pollutant concentrations by run type for the urban and rural/suburban routes, under open and closed window conditions. Both window position and surrounding traffic density can be seen to have strongly affected on-board concentrations for vehicle-related pollutants, but for pollutants with a strong background component, such as $PM_{2.5}$ and fine particle counts (0.3-0.5 µm), differences between routes and differences due to window position were less distinct..

Table 1.2. Concentrations means and range of means by route and by window position[1].

Pollutant	Urban Route[1]				Rural/Suburban Route	
	Windows Closed (a.m.)[2]		Windows Open (p.m.)[2]		Windows Open (p.m.)[2]	
	Mean	Range of Means	Mean	Range of Means	Mean	Range of Means
Black Carbon (µg/m³)	10	2.5 – 19	5.2	2.9 – 9.1	2.7	0.9 – 4.8
PM-bound PAH (ng/m^3)	198	64 – 400	96	33 – 147	36	14 – 66
NO_2 (ppb)	64	34 – 110	73	39 – 120	45	23 – 68
Formaldehyde (µg/m^3)	2.1	0.89 – 4.8	1.1	0.55 – 2.1	0.93	0.34 – 2.0
Particle Counts (#/cm³)	113	51 – 235	96	19 – 276	159	29 – 253
Carbon Monoxide (ppm)	5.1	3.7 – 6.4	2.4	1.9 – 2.9	na[3]	na[3]

[1]Includes commutes on urban route one only. [2]Windows closed in morning and open in afternoon, similar to conditions uniformly observed in other buses in Los Angeles for April through June. [3]No measurements conducted.

Conclusions: Measurements made on-board school buses in Los Angeles indicated higher exposures are occurring during children's commutes than ambient air concentrations would indicate. These exposures resulted primarily from the commute itself, and not from loading, unloading, or waiting at bus stops. High commute exposures had several causes: the high concentrations of pollutants already present on roadways, especially if traffic was heavy; the direct influence of other vehicles being followed; and the contribution of the bus's own emissions. The extent of a bus's own contribution to these high concentrations appeared to be higher when windows were closed and for older buses. However bus-to-bus variability was relatively high and therefore with the small number of buses studied, and the limited number of routes covered, the findings of this study should not be viewed as inherently typical for all buses under all conditions. However, minimizing commute times, using the cleanest buses for the longest bus routes, and reducing bus "caravanning" and unnecessary idling time would reduce children's exposures to bus-related pollutants.